Immersion Nozzle for Continuous Casting

and

Continuous Casting Method Using the Immersion Nozzle

Technical Field

The present invention relates to an immersion nozzle for continuous casting of a molten metal such as molten steel or the like and a continuous casting method using the same.

Background Art

In a continuous casting, such as a wide slab casting, which provides a molten metal into a mold with the use of an immersion nozzle having a pair of outlet ports facing each other, a fluid in the mold causes fluctuation of a certain period, that is, the self-excited oscillation, so that a flow velocity fluctuation or bath level oscillation of the molten metal in the mold is likely to occur. As a result, a slab surface causes trouble in quality due to a non-metal inclusion, bubble, mold powder or the like caught in a solidified shell in the mold. In the case that a flow rate of the molten metal from the outlet ports is high such as a high speed casting, these problems are noticeable. Thus, it has been necessary to decrease a casting speed.

Conventionally, in order to control the flow in the mold,

for example, a method using an electromagnetic brake or electromagnetic stirring by electromagnetic force disclosed in International Publication No. WO99/15,291, a swirl flow generating immersion nozzle mounting a swirl blade inside of the nozzle disclosed in Japanese Patent Application Laid-Open (JP-A) No.2002-239,690, an immersion nozzle having deeper depth of a waterfall basin-like recess at the bottom disclosed in Japanese Patent No. 3,027,645 (JP-A No. Hei. 5(1993)-169,212), an immersion nozzle provided with a bump inside of the nozzle disclosed in Japanese Patent No. 3,207,793 (JP-A No. Hei. 11(1999)-123,509) and so on are invented.

However, since a design cost of the method using the electromagnetic force is high, a merit which matches the high investment often cannot be obtained. Also, since it is difficult to sense a molten metal flow which is an object to be controlled, the control is performed but the condition of the object to be controlled often remains unclear. Hence, it is difficult to exhibit sufficient effect technically. On the other hand, the effectiveness of the technique of the swirl flow generating immersion nozzle as a root measure which can stabilize the flow in the mold is confirmed. However, in the case of casting a molten metal having a low cleaning level containing a lot of non-metal inclusions, there is a problem that casting of vast amount of molten metal cannot be performed continuously since the non-metal inclusion is likely to be attached to the swirl blade inside of the nozzle. Also, the

nozzle provided with the bump inside of the nozzle or the immersion nozzle having deeper depth of the waterfall basin-like recess at the bottom can stabilize the fluid inside of the immersion nozzle, eventually, in the mold. However, since the effect is small, further improvement is still required.

JP-A No. Hei. 6(1994)-218,508 discloses an immersion nozzle which generates a turbulent flow in a molten steel flow of a molten pool part by providing a conical projection or a truncated conical projection on the molten pool part at a bottom part of an in-nozzle of immersion so as to prevent segregation of a deposit.

A form of the conical projection or the truncated conical projection at the molten pool part of the immersion nozzle disclosed in JP-A No. Hei. 6(1994)-218,508 is central axial symmetry such as a conical form or polyhedral cone. By such a form, the segregation of the deposit can be prevented at the molten pool part. However, there is no particular mention in JP-A No. Hei. 6(1994)-218,508 regarding stabilization of the flow in the mold.

Disclosure of Invention

An object of the present invention is to provide an immersion nozzle for continuous casting which enables improvement in quality of a slab surface and a long-time and

continuous increase in the efficiency of casting by suppressing the self-excited oscillation of a flow in a mold without using a complicated mechanism such as a swirl flow generating immersion nozzle.

In order to attain the above object, in a study done by the inventor of the present invention to control the flow in the mold, an appropriate form of the vicinity of outlet ports of the immersion nozzle has been sought. As a result, effective means thereof is found.

That is, a first immersion nozzle for continuous casting of the present invention is a nozzle comprising a cylindrical body and a pair of outlet ports formed to face each other in a side wall in the vicinity of a bottom part of the cylindrical body, wherein a ridge-shaped projection extending parallel with a discharge direction projected on a cross section of the nozzle is formed on an inner surface at the bottom part, which is formed in a waterfall basin-like recessed shape having a maximum depth of 5 mm to 50 mm.

Also, a second immersion nozzle for continuous casting of the present invention is an immersion nozzle for continuous casting, which is a nozzle, wherein each sectional area of the outlet ports vertical to a discharge direction projected on a cross section or longitudinal section of the nozzle is decreased toward an exit.

A continuous casting method provided by the present invention is a continuous casting method using the immersion

nozzle for continuous casting of the present invention under the condition that an average descend flow rate of a molten metal "U" of a portion immediately above an outlet port of a body is 1.0 m/s to 2.5 m/s.

According to the immersion nozzle for continuous casting of the present invention, the molten metal can be stably discharged from the immersion nozzle without using a complex mechanism such as the swirl flow generating immersion nozzle. Hence, the self-excited oscillation of a flow in a mold is suppressed, as a result, improvement in quality of a slab surface, and increase in the efficiency of a long-time casting are possible. The immersion nozzle for continuous casting and the continuous casting method using the same of the present invention are particularly suitable for the slab casting. A slab having less surface defect and inner defect can be produced.

Brief Description of Drawings

In the accompanying drawings,

FIG. 1A is a schematic diagram showing two vortexes having axes of rotation in discharge directions viewed from the front of an outlet port;

FIG. 1B is a schematic diagram showing a vortex on the near side among two vortexes having the axis of rotation in the discharge direction in a section view of the direction which

cuts outlet ports longitudinally;

FIG. 2 is an external view (in the state that the outlet port is shown in either side) from the side of outlet ports of an immersion nozzle for continuous casting of the present invention;

FIG. 3 is an external view showing the immersion nozzle for continuous casting of the present invention viewed from the front of an outlet port;

FIG. 4A is a cross section showing a first immersion nozzle for continuous casting of the present invention cut at the higher position than outlet ports;

FIG. 4B is an A-A section view of FIG. 4A (a section view in the direction of crossing a ridge-shaped projection);

FIG. 4C is a B-B section view of FIG. 4A (a section view in the direction of moving down through the outlet ports);

FIGs. 5A to 5J are various examples of ridge-shaped projections provided on an inner surface of a bottom part of an immersion nozzle for continuous casting of the present invention, each of which shows a section view of the ridge-shaped projection and the bottom part of the nozzle in the direction of moving down through two outlet ports;

FIG. 6 is a section view showing an example of outlet ports of the immersion nozzle for continuous casting of the present invention in the direction of moving down through the outlet ports;

FIG. 7 is a section view showing an example of outlet ports

of the immersion nozzle for continuous casting of the present invention in the direction of moving down through the outlet ports;

FIG. 8 is a section view showing an example of outlet ports of the immersion nozzle for continuous casting of the present invention in the direction of moving down through the outlet ports;

FIG. 9 is a section view showing a constitution of an immersion nozzle for continuous casting in Example 3;

FIG. 10 is a section view showing a constitution of an immersion nozzle for continuous casting in Example 5; and

FIG. 11 is a section view showing a constitution of an immersion nozzle for continuous casting in Comparative example 7.

The signs in each figure refer to the following: 1: a nozzle body; 2: a bottom part of a nozzle; 3: a side wall of a nozzle; 3': an inside wall of a nozzle; 4a, 4b: outlet ports; 4_{in}: an outlet port entrance; 4_{out}: an outlet port exit; 5: a ridge-shaped projection; 6a, 6b: upper walls of outlet ports; 7a, 7b: lower walls of outlet ports.

Best Mode for Carrying Out the Invention

The inventor of the present invention has repeated a full scale water model experiment of an immersion nozzle comprising a cylindrical body and a pair of outlet ports formed to face

each other in a side wall in the vicinity of a bottom part of the cylindrical body by changing a form in the vicinity of outlet ports in various way. As a result, it has been found that a flow which descends inside of the immersion nozzle hits the bottom part of the nozzle and discharges while forming two vortexes having axes of rotation in an discharge direction as shown in FIGs. 1A and 1B; the size of the vortexes formed at the bottom part fluctuates; and sometimes only one vortex thereof is present depending on the fluctuation of the size of the vortex formed at the bottom part. Furthermore, it has been found that the fluctuation of the size of the vortex formed at the bottom part disturbs a discharge flow from the immersion nozzle, and eventually, the flow in the mold is unstably fluctuated.

As a result of further study, the inventor of the present invention has found out that by providing a ridge-shaped projection extending parallel with the discharge direction projected on a cross section of the nozzle on an inner surface at the bottom part, stable vortexes heading to two outlet ports facing each other are formed in two regions separated by the ridge-shaped projection respectively when a downward flow which reaches the bottom part changes to vortexes having axes of rotation in the discharge direction, and thereby a discharge flow stabilizes.

Also, it has been found that an inner surface of the bottom part with a waterfall basin-like recessed shape having a maximum

depth of 5 mm to 50 mm is effective in order to suppress the self-excited oscillation of the flow in the mold. Herein, the "waterfall basin-like recessed shape" means a recessed shape surrounded by an inner wall lower than a lower wall of the outlet port. By forming the bottom part of the immersion nozzle in the waterfall basin-like recessed shape, a downward flow inside of the nozzle bounces due to the waterfall basin-like recessed shape when a downward flow distribution inside of the nozzle is uneven. As a result, a reversing flow is formed. Since the reversing flow has an effect to distribute a molten metal on the other side of the downward flow inside of the nozzle, distribution of the discharge flow is adjusted resulting in stabilization of the discharge flow.

The immersion nozzle disclosed in JP-A No. Hei. 6(1994)-218,508 as aforementioned as a conventional technique has the conical projection or the truncated conical projection on the molten pool part at the bottom part of the in-nozzle of immersion. The conical projection or the truncated conical projection disclosed in JP-A No. Hei. 6(1994)-218,508 is in a form of central axial symmetry such as a conical form or a polyhedral cone, that is to say, in a form having a uniform form in any angle of 360° around an axis of an immersion nozzle being a center.

To the contrary, the ridge-shaped projection on the inner surface of the bottom part of the nozzle of the present invention present is in a thin form extending substantially parallel with

the discharge direction of the molten steel projected on the cross section of the nozzle, that is to say, in a thin and long form in the discharge direction. Therefore, the present invention and the invention of JP-A No. Hei. 6(1994)-218,508 are basically different in a projection form.

Furthermore, the present invention and the invention of JP-A No. Hei. 6(1994)-218,508 are also different from the viewpoint of the effect of the projection form. In the invention of JP-A No. Hei. 6(1994)-218,508, the molten steel is uniformly dispersed in the vicinity of the projection, and further, the molten steel flow is stirred in the molten pool part at the bottom part so as to be a turbulent flow. Thereby, segregation of a deposit can be suppressed. However, the conical projection or the truncated conical projection of the invention of JP-A No. Hei. 6(1994)-218,508, does not have the effect of forming a stable vortex of the molten steel flow in the vicinity of outlet ports.

To the contrary, in the present invention, vortexes of the molten steel flow each of which has an axis of rotation in the discharge direction are stably formed on both sides of the ridge-shaped projection viewed from the front of the outlet port. Thereby, the discharge flow and the molten steel flow in the mold stabilize.

A first immersion nozzle for continuous casting of the present invention is invented based on the above knowledge. Examples of constitution of the first immersion nozzle for

continuous casting of the present invention are shown in FIGs. 2 to 4. FIG. 2 shows an external view (in the state that the outlet port is shown in either side) from the side of outlet ports of the immersion nozzle for continuous casting of the present invention. FIG. 3 shows an external view showing the immersion nozzle for continuous casting of the present invention viewed from the front of an outlet port. Also, FIG. 4A shows a cross section of the first immersion nozzle for continuous casting of the present invention cut at higher position than the outlet ports. FIG. 4B shows an A-A section view of FIG. 4A (a section view in the direction of crossing a ridge-shaped projection). FIG. 4C shows a B-B section view of FIG. 4A (a section view in the direction of moving down through outlet ports).

Hereinafter, the present invention will be explained in refer to FIG. 4. The first immersion nozzle of the present invention comprises a cylindrical body 1 and a pair of outlet ports 4a and 4b formed to face each other in a side wall 3 in the vicinity of a bottom part 2 of the cylindrical body 1, wherein a ridge-shaped projection 5 extending parallel with a discharge direction projected on a cross section of the nozzle is formed on an inner surface 2 at the bottom part, which is formed in a waterfall basin-like recessed shape having a maximum depth of 5 mm to 50 mm.

The waterfall basin-like recessed shape exhibits its effect when the maximum depth "H" is set in the range of 5 mm

to 50 mm. Herein, the maximum depth "H" means a distance between a position where a lower wall of the outlet port and an inner wall of the nozzle body cross and the deepest position of the waterfall basin-like recess. If the maximum depth "H" is below 5 mm, the effect by forming the waterfall basin-like recessed shape cannot be obtained. On the other hand, if the maximum depth "H" exceeds 50 mm, a non-metal inclusion is attached and deposited to the waterfall basin-like recess, and additionally, the immersion nozzle becomes too long. Thus, handling may be deteriorated. It is more preferable that the maximum depth "H" of the waterfall basin-like recessed shape is 10 mm to 30 mm. As the form of the waterfall basin-like recess, a portion not having the ridge-shaped projection 5 formed may be horizontal, inclined, or concave on a spherical surface.

A form of the ridge-shaped projection 5 may not be particularly limited if the ridge-shaped projection 5 is provided on the inner surface of the bottom part of the nozzle parallel with the discharge direction projected on the cross section and can form a stable vortex formed at the bottom part. Examples of constitution of the ridge-shaped projection 5 are shown in FIGs. 5A to 5J (section views in the direction of moving down through two outlet ports). For example, a height in the section view cut in the direction of moving down through outlet ports (hereafter, it may be solely referred as height), that is, a ridgeline may be or may not be constant as shown in FIG. 5A. As examples of cases not having constant height,

specifically, there may be FIGs. 5B and 5C having a peak in the central part of the cross section of the nozzle and having ridgelines from the peak lowering toward two outlet ports, FIGs. 5D in a trapezium, that is, having a horizontal apex in the vicinity of the central part of the cross section of the nozzle and having ridgelines from the apex lowering toward two outlet ports or the like. In this case, the ridgeline may be a continuous incline such as linear, radial or the like, or may be a non-continuous incline such as trapezium or stepwise.

The ridgeline may reach a position lower than the lower wall of the outlet port of the side wall of the waterfall basin-like recessed shape portion (for example, FIGs. 5A to 5D), may reach the bottom part in the vicinity of outlet ports of the cross section of the nozzle so that the ridge-shaped projection 5 itself is terminated (for example, FIGs. 5E to 5G), or may reach the bottom part in the vicinity of the central part of the nozzle so that the ridge-shaped projection 5 is provided only in the vicinity of the central part of the cross section of the nozzle (for example, FIGs. 5H to 5J). In the case that the ridge-shaped projection 5 terminates in the vicinity of outlet ports of the cross section of the nozzle or provided only in the vicinity of the central part of the cross section of the nozzle, the ridgeline which descends vertically from a horizontal apex or in the course of lowering toward outlet ports and reaches the bottom part of the nozzle is included (for example, FIGs. 5G and 5J). Herein, in the case of a general

immersion nozzle having an inner diameter of about 80 to 90 mm, "in the vicinity of outlet ports of the cross section of the nozzle" means a range about 15 mm from an outlet port entrance of the cross section of the nozzle. "In the vicinity of the central part of the cross section of the nozzle" means a range from a center to a radius of about 20 mm of the cross section of the nozzle.

As a result of further study with the water model experiment, the inventor of the present invention has found that if the size of the ridge-shaped projection 5 is too large, there is a flow condition similar to the case that the depth of the waterfall basin-like recess is shallow so that the effect of forming the waterfall basin-like recessed shape cannot be fully exhibited. Then, further study has been done by the inventor of the present invention. As a result, it has been found that the ridge-shaped projection 5 preferably has the following form in order to exhibit the effect of the waterfall basin-like recessed shape and the ridge-shaped projection 5 sufficiently and in good balance.

That is, the preferable form of the ridge-shaped projection 5 is a form wherein the height in the central part or in the vicinity thereof of the cross section of the nozzle is highest and the height in the vicinity of an outlet port entrance of the cross section of the nozzle is low. Since a flow rate of a downward flow inside of the nozzle in the central part and in the vicinity thereof of the cross section of the

nozzle is high, by providing the ridge-shaped projection having highest height in the central part or in the vicinity thereof of the cross section of the nozzle as mentioned above, a vortex formed at the bottom formed when the downward flow inside of the nozzle hits the bottom part of the nozzle can be formed more effectively and stably. Also, in the case of a ridge-shaped projection having low height in the vicinity of the outlet port entrance, a vortex formed at the bottom part is likely to enter the bottom part of the waterfall basin-like recess. Hence, the effect of bouncing the downward flow by the waterfall basin-like recessed shape inside of the nozzle can be further increased.

In the above-mentioned preferable form of the ridge-shaped projection 5, the highest portion of the central part or in the vicinity thereof of the cross section of the nozzle may be a peak or a horizontal apex. Also, "low height in the vicinity of the outlet port entrance" includes a case that the ridgeline of the ridge-shaped projection 5 lowers from the peak of the ridge-shaped projection 5 or from the peak of the ridge-shaped projection 5 toward two outlet ports and reaches the position lower than the lower wall of the outlet port of the side wall of the waterfall basin-like recessed shape portion, a case that the ridge-shaped projection 5 itself is terminated in the vicinity of the outlet port entrance of the cross section of the nozzle, a case that the ridge-shaped projection 5 is solely provided in the vicinity of the central part of the cross section of the nozzle or the like.

Specifically, as the preferable form of the ridge-shaped projection 5, there may be, firstly, a case having a peak or a horizontal apex in the central part or in the vicinity thereof of the cross section of the nozzle, wherein the ridgeline reaches a position lower than the lower wall of the outlet port of the side wall of the waterfall basin-like recessed shape portion while lowering toward two outlet ports from the peak or the horizontal apex. Specifically, there may be cases shown in FIGs. 5B, 5C and 5D. Also, there may be a case having a peak or a horizontal apex in the central part or in the vicinity thereof of the cross section of the nozzle, wherein the ridgeline reaches the bottom part in the vicinity of the outlet port entrance of the cross section of the nozzle while lowering toward two outlet ports from the peak or the horizontal apex so that the projection itself is terminated. Specifically, there may be cases shown in FIGs. 5E, 5F and 5G. Furthermore, there may be a case having a horizontal apex in the central part or in the vicinity thereof of the cross section of the nozzle, wherein the ridgeline reaches the bottom part by lowering toward two outlet ports from the horizontal apex or descending vertically so that the ridge-shaped projection is only provided in the central part or in the vicinity thereof of the cross section of the nozzle. Specifically, there may be cases shown in FIGs. 5H and 5J.

It is preferable that the ridge-shaped projection 5 has the above-mentioned preferable form, and at the same time, the

maximum height of the ridge-shaped projection is as same as the maximum depth of the waterfall basin-like recess "H" or in the range of ±10 mm of the maximum depth of the waterfall basin-like recess "H", and the maximum height of the ridge-shaped projection is 5 mm to 50 mm. If the maximum height of the ridge-shaped projection is less than 5 mm, the effect of the ridge-shaped projection cannot be sufficiently obtained. On the other hand, if the maximum height of the ridge-shaped projection exceeds 50 mm, it is difficult to maintain the strength due to a structural problem and produce the nozzle.

As for a thickness of the ridge-shaped projection 5 (the cross section of the ridge-shaped projection 5), it is preferable that an upper part of the projection may be about 5 mm to 15 mm since if a thickness of the upper part of the projection is too thin, durability of the projection may be insufficient. If the thickness of the upper part of the projection is too thick, it has an adverse effect to formation of vortexes. A lower part of the projection may have the same thickness as the upper part of the projection or may be in a form which increases thickness from the upper part toward the lower position so as to broaden toward the end.

The ridge-shaped projection 5 is generally disposed in the central part on the inner surface of the bottom part of the nozzle so as to divide the inner surface of the bottom part of the nozzle equally, that is, a position symmetric with respect to a central axis of the nozzle body. However, it is not

necessary that the ridge-shaped projection 5 is disposed in the central part of the inner surface of the bottom part of the nozzle. In the case that the downward flow inside of the nozzle is to descend unevenly due to a sliding gate or the like disposed at an upper part of the nozzle, the ridge-shaped projection 5 may be disposed with a shift from the central part on the inner surface of the bottom part of the nozzle according to the unevenness of the downward flow inside of the nozzle.

By providing the ridge-shaped projection, the flow becomes similar to the condition that the height of the waterfall basin-like recess is shallow. Thus, there may be a case that the effect of the waterfall basin-like recess cannot be sufficiently obtained. The inventor of the present invention has found out that if the waterfall basin-like recessed shape at the bottom part is expanded to the discharge direction projected on the cross section and is in a form of an ellipse or oval having larger size than the inner diameter of the nozzle body in the first immersion nozzle for continuous casting of the present invention, the above problem can be solved and the effect of the waterfall basin-like recessed shape can be increased. The stable vortexes formed at the bottom part by the ridge-shaped projection are strong vortexes with axes of rotation in the discharge direction and are progressive flows in the discharge direction. Such a flow is in the similar state as a flow having high viscosity and is not likely to enter the bottom of a small concave. Hence, in order that the flow can

enter the waterfall basin-like recess and be bounced, it is necessary to enlarge a sectional area of the waterfall basin-like recess so that the flow easily enters the bottom of the waterfall basin-like recess. Therefore, in the immersion nozzle of the present invention, in which stable and strong vortexes can be formed by the ridge-shaped projection, it is assumed that the effect of the waterfall basin-like recess can be further improved by the waterfall basin-like recess in a form of the ellipse or oval having larger size than the inner diameter of the nozzle body as mentioned above. Also, such an effect of the waterfall basin-like recess can be obtained when the inner diameter of the nozzle body itself is in a form of the ellipse or oval expanded in the discharge direction.

Furthermore, the inventor of the present invention has found out that it is important that the discharge flow is discharged without being detached (separated) from a side wall or an upper and lower wall of the outlet port in order to stabilize the discharge flow, other than the effect by the ridge-shaped projection and the waterfall basin-like recess. This is because fluctuation itself of the discharge flow running distantly and along the wall makes the flow unstable, and additionally, because the phenomenon, wherein the amount of the non-metal inclusion contained in the molten metal which attaches to the outlet port increases in the immersion nozzle for continuous casting due to such a disturbance of the flow, and the form of the outlet port changes in accordance with

proceeding of casting so as to destabilize the discharge flow, is caused.

A second immersion nozzle for continuous casting of the present invention has been invented based on the above knowledge. The second immersion nozzle for continuous casting of the present invention is a nozzle comprising a cylindrical body and a pair of outlet ports formed to face each other in a side wall in the vicinity of a bottom part of the cylindrical body, wherein each sectional area of the outlet ports vertical to a discharge direction projected on a cross section or longitudinal section of the nozzle is decreased from an entrance toward an exit.

Examples of constitution of the first immersion nozzle for continuous casting of the present invention are shown in FIGs. 6 to 8. FIGs. 6 to 8 are section views in the direction of moving down through the outlet ports of the second immersion nozzle for continuous casting of the present invention.

Hereinafter, the present invention will be explained in refer to FIG. 6. The second immersion nozzle of the present invention comprises a cylindrical body 1 and a pair of outlet ports 4a and 4b formed to face each other in a side wall 3 in the vicinity of a bottom part 2 of the cylindrical body 1, wherein each sectional area of the outlet ports vertical to a discharge direction projected on a cross section or longitudinal section of the nozzle is decreased from an outlet port entrance 4_{in} toward an exit 4_{out}.

By decreasing each sectional area of the outlet ports

vertical to the discharge direction projected on the cross section or longitudinal section of the nozzle from the outlet port entrance 4_{in} toward the outlet port exit 4_{out}, separation of the discharge flow from an outlet port wall can be prevented, and thereby the discharge flow can be stabilized. Furthermore, since stagnation of the discharge flow in the vicinity of the outlet ports is less likely to occur, attaching of the non-metal inclusion contained in the molten metal or the like to the outlet ports can be suppressed and generation of blockage of the outlet ports and defect of a slab due to peeling of the deposit can be prevented. Thus, stable operation and quality of slab can be secured even by casing for a long time.

The sectional area of the outlet port may be gradually narrowed or steeply narrowed in the vicinity of the exit. However, it is not preferable if the degree of narrowing is too steep from the viewpoint of stably discharging the discharge flow and preventing attachment of the non-metal inclusion. Also, the sectional area of the outlet port may be decreased in the direction of height or width, or in both directions of height and width.

The downward flow inside of the nozzle changes direction at the bottom part of the nozzle so as to have a rate vector in the horizontal direction, and enters the outlet port obliquely downward. Due to the characteristic of the flow in the vicinity of the outlet port, the discharge flow is to be discharged along the lower wall of the outlet port. Therefore,

if the height of the outlet port is too high, the discharge flow separates from the upper wall of the outlet port. As measures to prevent separation of the discharge flow, it is preferable that the second immersion nozzle for continuous casting of the present invention has outlet ports having horizontally long width longer than the height of the outlet ports. As the horizontally long form, specifically, it is preferable that an average height of the outlet port exit is 0.5 to 0.9 times of an average width of the outlet port exit. It is not preferable if the average height of the outlet port exit is less than 0.5 times of the average width of the outlet port exit, since the area of the outlet port is not enough. If the average height of the outlet port exit exceeds 0.9 times of the average width of the outlet port exit, the effect of the horizontally long outlet port cannot be obtained. The form of the outlet port may not be particularly limited if it is in a horizontally long form as mentioned above, for instance, a polygon other than a quadrangle, an ellipse, an approximate quadrangle having "R" at the corners or the like.

Furthermore, as shown in FIGs. 7 and 8, it is preferable that each upper wall of the outlet ports 6a or 6b of the second immersion nozzle for continuous casting of the present invention is in a circular form having a curvature radius of R 30 mm to R 150 mm and has a cross section of expanding inner diameter from the inner wall of the nozzle body 3' toward the upper wall of the outlet port, and an angle of each lower wall

of the outlet ports 7a or 7b may be in the range of 15°upward to 45° downward, within the range for the purpose of decreasing the sectional area of the outlet port toward the exit thereof. FIG. 7 shows a case that the angles of the lower walls of the outlet ports 7a and 7b are 15° upward. FIG. 8 shows a case that the angles of the lower walls of the outlet ports 7a and 7b are 45° downward. By forming the upper wall of the outlet port in such a form, the flow obliquely downward in the vicinity of the outlet port discharges along the upper wall of the outlet port. Thus, separation of the discharge flow from the upper wall of the outlet port can be effectively prevented.

If the curvature radius "R" of the upper wall of the outlet port is smaller than 30 mm, separation of the discharge flow is more likely to occur since decrease of the sectional area of the outlet port is not sufficient and the discharge flow cannot be discharged along the upper wall due to a steep curvature. Also, if the curvature radius "R" of the upper wall of the outlet port is larger than 150 mm, the thickness of the nozzle at the upper wall of the outlet port may decrease so as to decline strength. On the other hand, if the angle of the lower wall of the outlet port is larger upward than 15° upward, the flow which goes up from the outlet port becomes strong so as to cause fluctuations of the bath level in the mold. Furthermore, if the angle of the lower wall of the outlet port is larger downward than 45° downward, the discharge flow deeply penetrates to the mold so that the supply of the molten metal

to the bath level of the mold may become insufficient. Thereby, the supply of heat to the bath level may be insufficient so as to decrease temperature of the bath level, thus, a problem that removing of the non-metal inclusion and bubble by floatation is inhibited may be raised. Furthermore, since it becomes difficult to decrease the sectional area of the outlet port toward the exit, an original purpose, which is to prevent separation of the discharge flow from the outlet port wall, cannot be attained.

In the case of an immersion nozzle for continuous casting of the present invention using each means employed for the first immersion nozzle for continuous casting and the second immersion nozzle for continuous casting of the present invention in combination, the flow of the discharge flow further stabilizes and the self-excited oscillation of the flow in the mold can be effectively suppressed due to the multiplier effect.

As aforementioned, by using the immersion nozzle for continuous casting provided by the present invention, the discharge flow from the immersion nozzle for continuous casting can be stabilized. Thus, the self-excited oscillation of the flow in the mold can be suppressed. As a result, a non-metal inclusion, bubble, mold powder or the like caught in a solidified shell can be prevented. Therefore, improvement in quality of a slab surface can be attained. Also, due to the effect of stabilized discharge flow, increase in the efficiency of casting can be attained. Specifically, a stable flow in a

mold can be formed for a long time even in the case of a high through put in which a discharge flow amount from the immersion nozzle is about 4.5 to 7.0 t/min.

Casting using the immersion nozzle for continuous casting of the present invention can form a stable discharge flow in the above-mentioned increase in the efficiency of casting. However, if further improvement in quality of slab is required, it is preferable that an average descend flow rate "U" of the molten metal inside of the nozzle of a portion immediately above the outlet port of the body is in the range of 1.0 m/s to 2.5 m/s. Herein, "the portion immediately above the outlet port" means a portion where the upper wall 6 of the outlet port and the inner wall 3' of the nozzle body cross. By having the average descend flow rate "U" of the molten metal inside of the nozzle within the above range, a particularly high effect of stabilization of the discharge flow, that is, an effect of stabilization of the flow in the mold can be obtained. If the average descend flow rate "U" of the molten metal inside of the nozzle of the portion immediately above the outlet port is below 1.0 m/s, the molten metal flow amount becomes small with respect to the inner diameter of the nozzle, thus, the descend flow inside of the nozzle becomes unstable. Due to the effect thereof, the discharge flow also becomes unstable. Therefore, under the casting condition of small amount of the molten metal flow amount, it is necessary to secure the average descend flow rate "U" of the molten metal inside of the nozzle of 1.0 m/s

or more by having a smaller inner diameter of the nozzle If the average descend flow rate "U" of the molten metal inside of the nozzle of the portion immediately above the outlet port exceeds 2.5 m/s, the descend flow rate inside of the nozzle becomes too high, and eventually, the discharge flow rate becomes too high. Thereby, problems such as fluctuation of bath level and remelting of a solidified shell in the mold may be raised.

The average descend flow rate "U" of the molten metal inside of the nozzle can be calculated by "(an average descend flow amount of a molten metal inside of a nozzle)/(a sectional area of a nozzle body)". Herein, "the average descend flow amount of the molten metal inside of the nozzle" is a value calculated by "(a casting speed of a slab) x (a sectional area of a slab) x (gravity of a slab)/(gravity of a molten steel)".

An inner diameter of the portion immediately above the outlet port is used for calculating the average descend flow rate "U" of the molten metal inside of the nozzle if the inner diameter of the nozzle body is diverse between an upper part of the nozzle and the portion immediately above the outlet port.

Examples

Hereinafter, the effect of the present invention will be explained with comparison between Examples and Comparative examples of the present invention.

Immersion nozzles for continuous casting comprising a cylindrical body and a pair of outlet ports formed to face each other in a side wall in the vicinity of a bottom part of the cylindrical body used in Examples 1 to 6 and Comparative examples 7 to 9 are shown in Table 1.

Table 1

	Example						Comparative example		
	1	2	3	4	5	6	7	8	9
Inner surface form at bottom part of nozzle	Waterfall basin-like form	Flat form	Waterfall basin-like form	Waterfall basin-like form	Waterfall basin-like form	Waterfall basin-like form	Flat form	Waterfall basin-like form	Waterfall basin-like form
Maximum depth of waterfall basin-like recess (mm)	15	0	15	15	15	35	0	15	30
Plain form of waterfall basin-like recess	Ellipse 80x90 (mm)	-	Round ϕ80 (mm)	Ellipse 90x110 (mm)	Ellipse 90x110 (mm)	Ellipse 80x90 (mm)	-	Round ϕ90 (mm)	Round ϕ90 (mm)
Maximum height of ridge-shaped projection at bottom part (mm)	15	0 (No projection)	18	8	15	30	0 (No projection)	0 (No projection)	0 (No projection)
Side form of ridge-shaped projection at bottom part	Base:90 mm Isosceles triangle	-	Base:50 mm Upper base: 20 mm Trapezium	Base:110 mm Height:8 mm Rectangle	Base:110 mm Isosceles triangle	Base:60 mm Isosceles triangle	-	-	-
Thickness of ridge-shaped projection at bottom part (mm)	10	-	10	Base: 12 Upper end: 7	10	Base: 15 Upper end: 8	-	-	-
Average height of outlet port exit (mm)	78	64	67	64	64	43	79	60	88
Average width of outlet port exit (mm)	78	89	79	89	89	70	86	72	58
Form of upper wall of outlet port	25° downward	R60 mm	R120 mm	R60 mm	R60 mm	R90 mm	15° downward	R40 mm	10° upward
Form of lower wall of outlet port	25° downward	15° downward	5° upward	15° downward	25° downward	10° downward	15° downward	45° downward	10° upward
Outer diameter of nozzle body (mm)	ϕ155	ϕ160	ϕ155	ϕ155	ϕ155	ϕ150	ϕ155	ϕ160	Φ160
Inner diameter of nozzle body (mm)	ϕ80	ϕ90	ϕ80	ϕ90	ϕ90	ϕ80	ϕ80	ϕ90	ϕ90
Descend flow amount inside of nozzle (m^3/s)	0.00885	0.00974	0.01062	0.01036	0.01166	0.00731	0.01151	0.01152	0.00540
Descend flow rate inside of nozzle (m/s)	1.76	1.53	2.11	1.63	1.83	1.45	2.60	1.81	0.85
Compatible claims	1,2,3,7	4,5,6,7	1,2,4,5,6,7	1,3,4,5,6,7	1,2,3,4,5,6,7	1,2,3,4,5,6,7	-	-	-
Flow stability index of mold	B	B	A	A	A+	A+	F	C	F

An average height and average width of an outlet port exit when a corner of an outlet port exit is in an "R" form can be obtained as follows. That is, a tetragonum not having an "R" form at a corner and having the same area as an outlet port, a corner of which is in an "R" form, is obtained by reducing both height and width of the outlet port. The height and the width of thus obtained tetragonum are referred as an average height and a width of an outlet port exit. For example, in FIG. 9 showing Example 3, a form of an outlet port exit is an approximate tetragonum having a height of 68 mm and a width of 80 mm and having "R" in a corner. If R 10 mm form of the corner is taken into account, the average height of the outlet port exit and the average width of the outlet port exit are respectively reduced by about 1 mm with respect to the height of the outlet port exit and the width of the outlet port exit. That is, the average height of the outlet port exit is 67 mm (decimal places are rounded off) and the average width of the outlet port exit is 79 mm (decimal places are rounded off). Similar methods of estimation of the average height of the outlet port exit and the average width of the outlet port exit are used for other Examples and Comparative examples.

(Evaluation method)

In Examples and Comparative examples shown in Table 1, a flow stability in a mold was evaluated using a full scale water model experiment, which is a simulative slab continuous casting

device having a mold thickness of 235 to 270 mm, a mold width of 1,500 to 2300 mm, by changing a size and a form of a bottom part and outlet ports of an immersion nozzle for continuous casting and a molten metal descend flow rate "U" inside of the nozzle. A constitution of an immersion nozzle for continuous casting used for each Example or Comparative example is shown in Table 1 as well as FIGs. 9 to 11 accordingly.

Herein, "the flow stability in a mold" is an evaluation of a value sorted by level, wherein the value was obtained by a standard deviation of measured data divided by an average value, which are flow rates in a direction of a mold width at 1/2 thickness and 1/4 width inside of the mold and 50 mm under water surface measured at two places at each side of the direction of the mold width for 15 minutes each in the full scale water model experiment. In the measurement, a propeller flow meter was used and the flow rate was measured by a pitch of 0.5 second. Since an instantaneous value data measured by a pitch of 0.5 seconds may significantly fluctuate due to the effect of a minute swirl, an average value for every 2.5 minutes of the data was used for the calculation of the standard deviation as a minimum unit.

Criteria of evaluation of the flow stability in a mold were "A+" (particularly excellent) for a value calculated by "standard deviation/average value" of less than 0.4; "A" (excellent) for a value calculated by "standard deviation/average value" of 0.4 or more and less than 0.5; "B"

(good) for a value calculated by "standard deviation/average value" of 0.5 or more and less than 0.6; "C" (passable) for a value calculated by "standard deviation/average value" of 0.6 or more and less than 0.7; and "F" (failed) for a value calculated by "standard deviation/average value" of 0.7 or more. From the experience of the inventor of the present invention, if the flow stability in the mold is "A+", "A" or "B", the flow in the mold is stable, oscillation of bath level and fluctuation of level are small and surface quality of a slab becomes excellent when the immersion nozzle is mounted in an actual device. Also, if the flow stability in the mold is "C" or "F", the flow in the mold is more likely to be unstable in the actual device, the oscillation of bath level in the mold and the level fluctuation tend to become large and surface quality of the slab tends to deteriorate.

(Evaluation result)

Example 1 is an immersion nozzle having characteristics of the first immersion nozzle for continuous casting of the present invention, wherein both waterfall basin-like recessed shape and ridge-shaped projection are formed in preferable shapes. That is, the waterfall basin-like recess formed on an inner surface of a bottom part of the nozzle is in a large ellipse form in a discharge direction projected on a cross section. A sectional view (side surface form) in a direction moving down through outlet ports of the ridge-shaped projection is in an

isosceles triangle form having a base of the same length as a major axis of the ellipse and a maximum height of the same length as a depth of the waterfall basin-like recess. The ridgeline reaches a bottom part of the nozzle at a position where the bottom part of the nozzle and the side wall of the nozzle cross. Therefore, swirls having axes of rotation in the discharge direction were stably formed at the bottom part of the nozzle. Furthermore, an excellent flow stability in the mold was obtained since the immersion nozzle was used under a preferable condition of the descend flow rate inside of the nozzle.

Example 2 is an immersion nozzle having characteristics of the second immersion nozzle for continuous casting of the present invention. In the immersion nozzle, sectional areas of the outlet ports vertical to the discharge direction projected on a cross section or longitudinal section of the nozzle are gradually decreased according to the relationship between an "R" form of an upper wall of an outlet port and an angle of a lower wall. Also, since the outlet ports were in a horizontally long form, a discharge flow was less likely to be separated from the upper wall of the outlet port. Furthermore, since the upper walls of the outlet ports were in a circular form and the angles of the lower walls was within a preferable range, a discharge flow outflowed without stagnation and separation of the discharge flow from the upper wall of the outlet port was effectively prevented. Further, since the immersion nozzle was used under a preferable descend

flow rate inside of the nozzle, excellent flow stability in the mold was obtained.

Example 3 is an immersion nozzle having both characteristics of the first and the second immersion nozzles for continuous casting of the present invention. Even though a flow stabilization effect at a bottom part of the nozzle by a waterfall basin-like recessed shape was weak since the waterfall basin-like recessed shape was not extended to a discharge direction projected on a cross section as shown in FIG. 9, a ridge-shaped projection and outlet ports are in preferable forms and the nozzle was used under a preferable condition of descend flow rate inside of the nozzle. Thereby, a stable discharge flow was formed. Particularly, due to a multiplier effect of having characteristics of the first and the second immersion nozzles at the same time, flow stability in the mold superior to that of Examples 1 and 2 was obtained.

Example 4 is an immersion nozzle having both characteristics of the first and the second immersion nozzles for continuous casting of the present invention. Since a ridge-shaped projection having the same height was provided from the central part on a cross section of the nozzle to a side wall of a waterfall basin-like recessed shape portion, a vortex having an axis of rotation in a discharge direction generated by the ridge-shaped projection was less likely to enter the waterfall basin-like bottom part, and a flow stabilization effect by the waterfall basin-like recess tended to decrease

slightly. However, since forms of the ridge-shaped projection, the waterfall basin-like recess and outlet ports were in preferable shapes and the nozzle was used under a preferable condition of a descend flow rate inside of the nozzle, a stable discharge flow was formed. Particularly, due to a multiplier effect of having characteristics of the first and the second immersion nozzles at the same time, flow stability in the mold superior to that of Examples 1 and 2 was obtained.

Examples 5 and 6 are immersion nozzles having both characteristics of the first and the second immersion nozzles for continuous casting of the present invention. Since a ridge-shaped projection, a waterfall basin-like recess and outlet ports were in preferable shapes and the nozzle was used under a preferable condition of a descend flow rate inside of the nozzle, a particularly stable discharge flow was formed. Hence, due to each technical element of the ridge-shaped projection, the waterfall basin-like recess and the outlet ports, particularly, due to a multiplier effect of having characteristics of the first and the second immersion nozzles at the same time, flow stability in the mold was the best of all. The immersion nozzle of Example 10 is shown in FIG. 10.

On the other hand, Comparative examples 7 to 9 are not compatible with the present invention.

As shown in FIG. 11, both waterfall basin-like recess and ridge-shaped projection were not provided on an inner surface at a bottom part of the nozzle in Comparative example 7.

Furthermore, sectional areas of outlet ports vertical to a discharge direction projected on a cross section or longitudinal section of the nozzle were constant. Hence, a discharge flow was not stabilized. Additionally, since a descend flow rate inside of the nozzle was high, a flow stability in a mold was "F".

An inner surface of a bottom part of an immersion nozzle of Comparative example 8 was formed in a waterfall basin-like recessed shape. However, since a ridge-shaped projection was not provided, a sufficiently stable vortex was not formed at the bottom part. Also, upper walls of outlet ports were in a circular form of R 40 mm, a wall inside of a body to the upper walls of the outlet ports was in a tube expansion form on a cross section, and angles of lower walls of the outlet ports were in a form downward to 45°. However, the combination of the form of the upper wall of R 40 mm and the form of the lower wall downward to 45° does not decrease the sectional areas of the outlet ports toward the exits, but rather the sectional areas in the vicinity of the exits were enlarged. Thus, a discharge flow was not stabilized and flow stability in the mold was "C".

An inner surface at a bottom part of a nozzle of Comparative example 9 was formed in a waterfall basin-like recessed shape. However, a ridge-shaped projection was not disposed. Hence, a sufficiently stable vortex was not formed at the bottom. Also, sectional areas of the outlet ports were constant, thus, a discharge flow was not stabilized.

Furthermore, since a descend flow rate inside of the nozzle was low, a discharge flow was unstable. Thus, flow stability in the mold was "F".